Physics 2A
Chapter 2: Kinematics in One Dimension

“Whether you think you can or think you can’t, you’re usually right.” – Henry Ford

“It is our attitude at the beginning of a difficult task which, more than anything else, will affect it’s successful outcome.” – William James

“The first and most important step toward success is the feeling that we can succeed.”
Nelson Boswell

Reading: pages 26 - 46

Outline:

⇒ position, distance, and displacement
⇒ speed and velocity
  average and instantaneous speed and velocity
⇒ acceleration
  average and instantaneous acceleration
⇒ motion with constant acceleration
  4 equations of constant acceleration
  applications of the 4 equations (examples)
⇒ graphical analysis of motion (covered in Lab 2: Motion Diagrams)
⇒ freely falling objects
  examples

Problem Solving

All constant-acceleration problems can be solved using the equations \( v = v_0 + at \),
\( x = \frac{1}{2} (v_0 + v)t \), \( x = v_0 t + \frac{1}{2} at^2 \) and \( v^2 = v_0^2 + 2ax \). **Note that these equations given in the text assume that \( x_0 = 0 \) m at \( t = 0 \) s.** If we **do not** make this assumption, then these equations become \( v = v_0 + at \), \( x - x_0 = \frac{1}{2} (v_0 + v)t \), \( x - x_0 = v_0 t + \frac{1}{2} at^2 \) and \( v^2 = v_0^2 + 2a(x - x_0) \). Six quantities appear in these equations: \( x, x_0, v, v_0, a, \) and \( t \). Mathematically, a typical constant-acceleration problem involves identifying the known and unknown quantities, then solving one of the kinematic equations for the unknown quantity. However, it is possible that you have two unknown quantities and need to simultaneously solve two of the kinematic equations. Finding solutions to simultaneous algebraic equations is discussed in the Mathematical Skills section below.

It is often helpful in solving a kinematics problem to fill in a table. For any problem, write numerical values next to given quantities and a question mark next to unknown quantity. There will usually be one equation that contains all of the known quantities and the unknown quantity.
Free-fall problems are exactly the same as other constant-acceleration problems for which the acceleration is given. The notation is different because we choose the $y$ axis to be vertical, so the object moves along that axis rather than the $x$ axis. You should realize that this is a superficial difference. The acceleration is always known ($g$, downward) and is usually not given explicitly in the problem statement. If up is defined as positive, then the acceleration due to gravity is $-g$ or $-9.8 \text{ m/s}^2$.

**Mathematical Skills**

**Simultaneous equations.**

You should be able to solve two simple simultaneous equations for two unknowns. For example, given any four of the algebraic quantities in $x - x_0 = v_0 t + \frac{1}{2} at^2$ and $v = v_0 + at$, you should be able to solve for the other two.

One way is to solve one of the equations algebraically for one of the unknowns, thereby obtaining an expression for the chosen unknown in terms of the second unknown. Substitute the expression into the second equation, replacing the first unknown wherever it occurs. You now have a single equation with only one unknown. Solve in the usual way, then go back to the expression you obtained from the first equation and evaluate it for the first unknown.

With a little practice you will learn some of the shortcuts. If the problem asks for only one of the two unknowns, eliminate the one that is not requested. If one equation contains only one of the unknowns, solve it immediately and use the result in the second equation to obtain the value of the second unknown. If one equation is linear in the unknown you wish to eliminate but the other equation is quadratic, use the linear equation to eliminate the unknown from the quadratic equation, rather than vice versa.

**Quadratic equations.**

You should be able to solve algebraic equations that are quadratic in the unknown.

If $At^2 + Bt + C = 0$, then

$$t = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

When the quantity under the radical sign does not vanish, there are two solutions. Always examine both to see what physical significance they have, then decide which is required to answer the particular problem you are working. If the quantity under the radical sign is negative, the solutions are complex numbers and probably have no physical significance for problems in this course. Check to be sure you have not made a mistake.
Questions and Example Problems from Chapter 2

Question 1
In the position vs. time graphs below, all the times are in seconds (s), and all the positions are in meters (m). Rank these graphs on the basis of which graph indicates the greatest average speed, where the average speed is calculated from the beginning to the end of motion. Give the highest rank to the one(s) with the greatest average speed, and give the lowest rank to the one(s) indicating the least average speed. If two graphs indicate the same average speed, give them the same rank.

Greatest 1 _______  2 _______  3 _______  4 _______  5 _______  6 _______  Least

Or, none of these are moving at all. ________________

Or, the average speed is the same for all of these. ___________

Please carefully explain your reasoning.

Now, rank these graphs on the basis of which graph indicates the greatest average velocity, where the average velocity is calculated from the beginning to the end of motion.

Greatest 1 _______  2 _______  3 _______  4 _______  5 _______  6 _______  Least

Or, none of these are moving at all. ________________

Or, the average speed is the same for all of these. ___________

Please carefully explain your reasoning.
**Question 2**
Listed below are six different situations that may or may not be possible. How many of the six situations are possible?

a) An object that undergoes acceleration while traveling at a constant speed.

b) An object that has a constant velocity and a varying speed.

c) An object that is moving when its acceleration is zero.

d) An object that is accelerating while traveling at a constant velocity.

e) An object that has a constant speed and a varying velocity.

f) An object that is accelerating when its speed is zero.

**Question 3**
The figure below give the acceleration $a(t)$ of a Chihuahua as it chases a German shepherd along an axis. (a) In which of the time periods indicated does the Chihuahua move at constant speed? (b) In which time periods is the Chihuahua’s speed increasing?

**Problem 1**
A car makes a 60.0 km trip with an average velocity of 40.0 km/h in a direction due north. The trip consists of three parts. The car moves with a constant velocity of 25 km/h due north for the first 15 km and 62 km/h due north for the next 32 km. With what constant velocity (magnitude and direction) does the car travel for the last 13 km segment of the trip?
Problem 2
A runner accelerates to a velocity of 5.36 m/s due west in 3.00 s. Her average acceleration is 0.640 m/s², also directed due west. What was her velocity when she began accelerating?

Problem 3
(a) What is the magnitude of the average acceleration of a skier who, starting from rest, reaches a speed of 8.0 m/s when going down a slope for 5.0 s? (b) How far does the skier travel in this time?

Problem 4
A jetliner, traveling northward, is landing with a speed of 69 m/s. Once the jet touches down, it has 750 m of runway in which to reduce its speed to 6.1 m/s. Compute the average acceleration (magnitude and direction) of the plane during landing.
Problem 5
Starting from rest, a speedboat accelerates at $+10.5 \text{ m/s}^2$ for a distance of 525 m. The engine is then turned off and the speedboat slows down at a rate of $-5.00 \text{ m/s}^2$. How long does it take for the speedboat to come to rest?

Problem 6
A speedboat starts from rest and accelerates at $2.01 \text{ m/s}^2$ for 7.00 s. At the end of this time, the boat continues for an additional 6.00 s with an acceleration of $+0.518 \text{ m/s}^2$. Following this, the boat accelerates at $-1.49 \text{ m/s}^2$ for 8.00 s. (a) What is the velocity of the boat at $t = 21.0 \text{ s}$? (b) Find the total displacement of the boat.
**Problem 7**
A drag racer, starting from rest, speeds up for 402 m with an acceleration of $+17.0 \, \text{m/s}^2$. A parachute then opens, slowing the car down with an acceleration of $-6.10 \, \text{m/s}^2$. How fast is the racer moving $3.50 \times 10^2 \, \text{m}$ after the parachute opens?

**Problem 8**
At the beginning of a basketball game, a referee tosses the ball straight up with a speed of $4.6 \, \text{m/s}$. A player cannot touch the ball until after it reaches its maximum height and begins to fall down. What is the minimum time that a player must wait before touching the ball?
**Problem 9**
An astronaut on a distant planet wants to determine its acceleration due to gravity. The astronaut throws a rock straight up with a velocity of +15.0 m/s and measures a time of 20.0 s before the rock returns to his hand. What is the acceleration (magnitude and direction) due to gravity on this planet?

**Problem 10**
A diver springs upward with an initial speed of 1.8 m/s from a 3.0-m board. (a) Find the velocity with which he strikes the water. (b) What is the highest point he reaches above the water?